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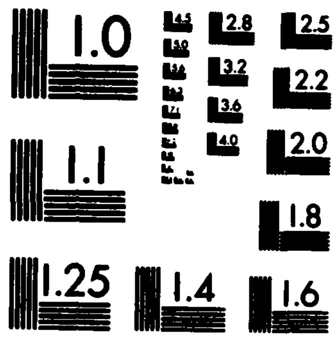

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ENVIRONMENTAL NOISE ASSESSMENT FOR MILITARY AIRCRAFT TRAINING ROUTES VOLUME 2: RECOMMENDED NOISE METRIC

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Operations on low level (MTRs) generate a unique noise environment unlike other community noise environments. A review of available information on the nature of, and potential subjective response to, this environment has been carried out. The noise exposure from MTR operations is well below threshold limits for hearing damage or other physiological effects. However, based on this review, an interim noise metric is recommended for evaluation of the potential annoyance response of communities to MTR noise environments. Keywords: Aircraft noise.

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Item 19, Abstract, Continued:

This recommended interim noise metric can be defined as follows.

- The numbers of events should be accounted for by a cumulative noise metric called the onset rate adjusted monthly day-night average, A-weighted sound level, abbreviated L_{dnmr}, based on an integration period equal to the calendar month with the highest number of operations.

- The spectral content and effect of onset rate for a single MTR noise event will be accounted for by an onset rate adjusted, sound exposure level, abbreviated L_{AEr}, equal to the sum of the A-weighted sound exposure level L_{AE} and an onset rate adjustment Δ_r. This adjustment is applied only when the maximum A-weighted fast sound level of the event exceeds the ambient by 15 dB.

- For MTR noise events with an onset rate equal to or less than 15 dB per second, the onset rate adjustment Δ_r will be 0. For onset rates between 15 and 30 dB per second, the onset rate adjustment, in decibels, is equal to $16.6 \log_{10} \left(\frac{\text{onset rate}}{15 \text{ dB/second}}\right)$. The onset rate adjustment is 5 dB for onset rates greater than 30 dB per second. This onset rate adjustment provides a noise penalty to account for increased intrusiveness due to the surprise factor of low level, high speed aircraft operations.

- Impact may be assessed in terms of the probability of high annoyance, utilizing existing relations between L_{dn} and annoyance.

These recommendations are based on the best available data, very little of which is directly applicable to MTRs. Until applicable data are available, the recommendations are supported only circumstantially, or by the argument that there are no data to show that anything else is better.

To protect Air Force needs in the long run, it is essential to conduct formal psychoacoustic studies which will provide an adequate data base to support or revise, if necessary, this interim noise metric.

SUMMARY

Operations on low level MTRs generate a unique noise environment unlike other community noise environments. A review of available information on the nature of, and potential subjective response to, this environment has been carried out. The noise exposure from MTR operations is well below threshold limits for hearing damage or other physiological effects. However, based on this review, an interim noise metric is recommended for evaluation of the potential annoyance response of communities to MTR noise environments.

This recommended interim noise metric can be defined as follows.

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1.0 INTRODUCTION

Beginning with the introduction of jet aircraft in the 1950s, a major consideration in aircraft operations planning has been the impact of noise on the community. A key element has been the development of appropriate metrics to characterize this noise. A variety of metrics evolved, to some degree interchangeable, which accounted for spectral content, duration, number of events, and time of day. Through the 1960s and 1970s, other noise sources (highways, railroads, construction, etc.) became matters of concern, and corresponding noise metrics were developed. By the mid to late 1970s in the United States, the plethora of metrics had been condensed in most cases to L_{dn}, the day-night average sound level. This metric accounts for spectral content via A-weighting, both duration and number of events via an equal-energy concept, and time of day via a 10 dB nighttime penalty. It has become almost universally accepted (impulsive noises such as sonic booms and artillery fire being notable exceptions), and is the prima facie metric to use for most situations. It is necessary, however, to assess whether the noise environment associated with low-level military training operations has unique features which fall outside the range of scientific support for L_{dn}.

The noise environment from low-altitude operations on military training routes (MTRs) is unique in several respects. Events are highly sporadic, ranging from a maximum of five to 10 per day to a minimum of a few (less than 10) operations every week or two. This differs from most community noise exposure scenarios which tend to be continuous or somewhat regular. Individual events are also different from typical community noise sources: the combination of low altitudes and high airspeeds results in noise signatures with high levels and short durations. Reference 1 contains a discussion of the nature of MTR operations and a preliminary discussion of the noise environments associated with these operations. Definitive data are not available to provide a final position for assessing the potential community noise impact of these unique events. However, until such research can be accomplished, there is a need to provide a metric based on the best available existing knowledge. In the time since Reference 1 was prepared, measurements have been conducted on one major type of route.[2] These data provide a reasonable definition of the noise characteristics of MTR operations such that a credible interim metric can be recommended. This report presents this recommended interim metric. The recommendation, which is conservative in nature, is that day-night average (A-weighted) sound level (L_{dn}) still provides a reasonable basis for describing the cumulative noise exposure of MTR operations, but an additional adjustment for the "surprise" effect of the

short onset time of aircraft is needed. There are no data currently available which clearly show that frequency weighting other than A-weighting, or that a number/duration factor other than that based on equal energy, is appropriate. It must be emphasized that the recommendation is based on extrapolations of best available data and, in some ways, is only circumstantially supported. In the long term, formal studies must be performed to obtain data which will support the Air Force's position.

Section 2.0 of this report presents a summary of the noise environment of MTRs, including data from Reference 2. Section 3.0 contains a review of the scientific basis of L_{dn} and places MTR environments into context. Section 4.0 presents an analysis of the surprise aspect of high-speed, low-altitude operations and derivation of an aircraft-dependent correction factor. Finally, Section 5.0 provides a summary of the recommended metric and an enumeration of questions which must still be answered in the long term.

2.0 MTR NOISE ENVIRONMENT

The nature of operations on MTRs is described in detail in References 1 and 2, with further description of TAC operations presented in Reference 3. The noise environment has the following characteristics:

- There are rarely more than 10 to 20 operations per day on the busiest routes, with an average of two to five operations per day on typical well-utilized routes. On some days there are no operations on even the busiest routes, and less used routes have averages of fractions of an operation per day.

- Aircraft flight tracks are dispersed laterally across the nominal centerline of the route. On SAC routes, this dispersion was found to be well described by a Gaussian distribution with a standard deviation of 0.5 mile.[2] On TAC routes, aircraft can be dispersed over the full range of the allowed lateral dispersion, which can be up to ± 5 miles from the route centerline. Routes used by other commands (MAC, ANG, etc.) are expected to fall between these extremes. This dispersion further reduces the number of operations affecting a given receptor.

- Individual flyovers are characterized by high noise levels and brief durations. Maximum noise levels for the bulk of current operations (minimum altitudes of 400 to 600 feet AGL) are in the range of 100 to 110 dB(A), with a sound exposure level (SEL) typically 3 to 5 dB higher.[2] Figures 1, 2, and 3 show typical time histories of A-weighted sound levels for a B-52H, B-1B, and FB-111 at altitudes corresponding to Terrain Avoidance (TA) operations. At lower altitudes (100 to 200 feet AGL is planned), sound levels will be higher and durations shorter than those at 400 to 600 ft AGL.

- Spectra do not differ dramatically from those experienced during flight conditions around air bases. Figures 4 and 5 show one-third octave band spectra for a B-52H and a B-1B recorded at the approximate time of maximum noise level.[2] Only a small fraction of the acoustic energy is at low frequencies (below 100 Hz), but levels in these low frequency bands are high enough (simply because of the overall level) to potentially cause rattling of light structures. This would be exacerbated at lower altitudes.

- The levels and durations noted above correspond to noise doses well within acceptable limits for hearing conservation.[4] Hearing damage, or any other

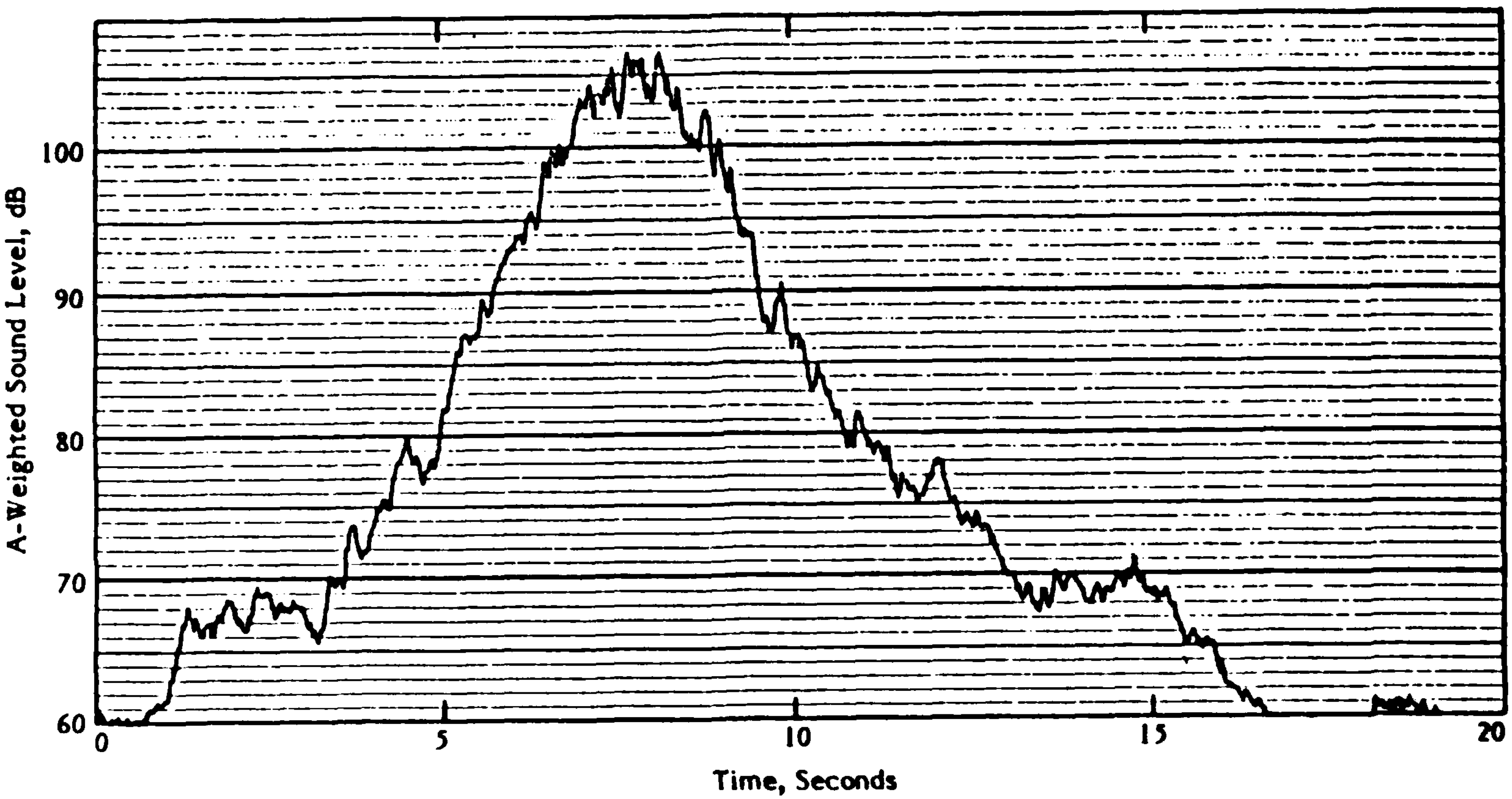

Figure 1. Time History of A-Weighted Sound Level, B-52H at TA Altitude, Directly Overhead.

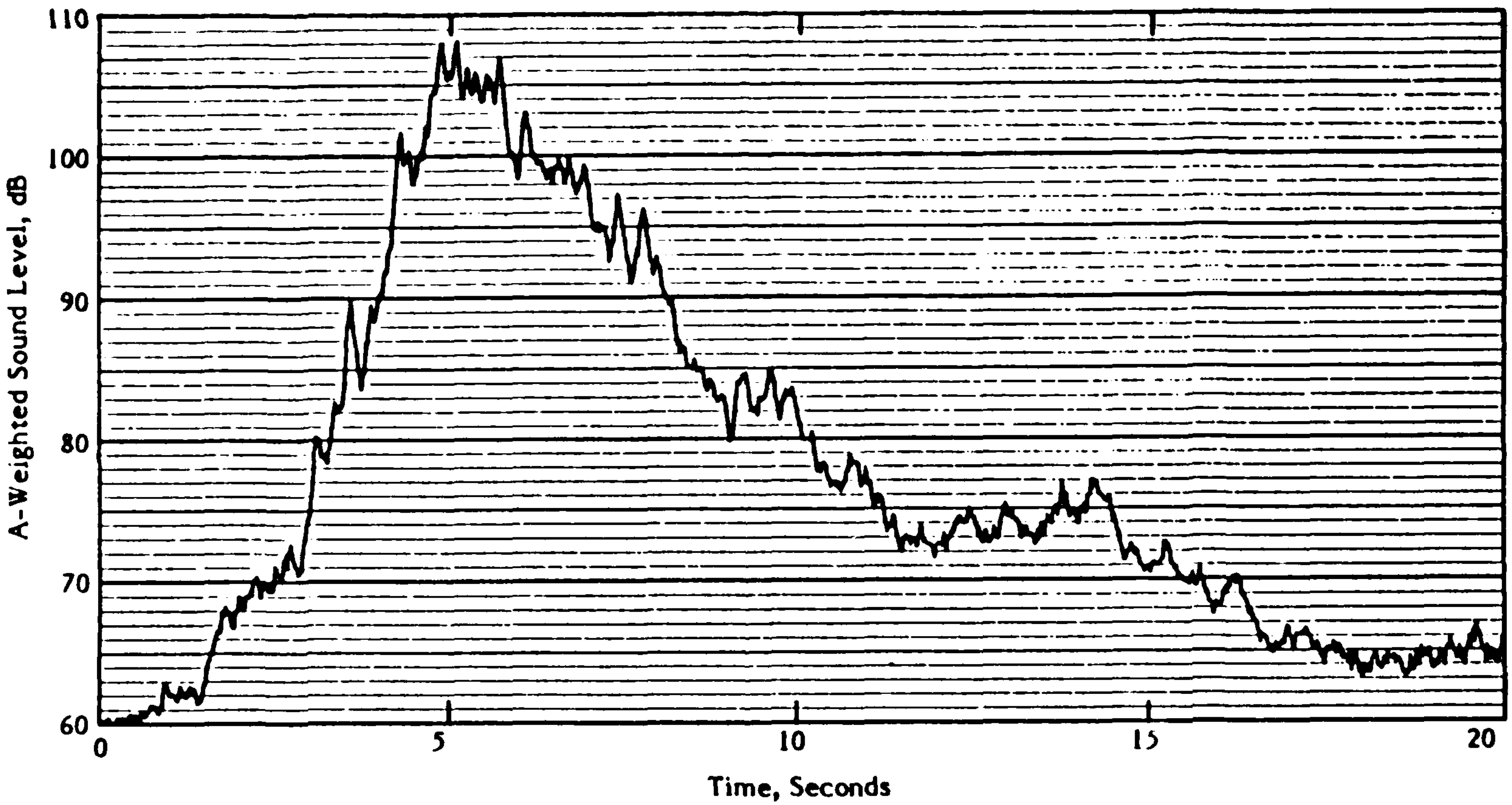

Figure 2. Time History of A-Weighted Sound Level, B-1B at TA Altitude, 500 ft Off-Track.

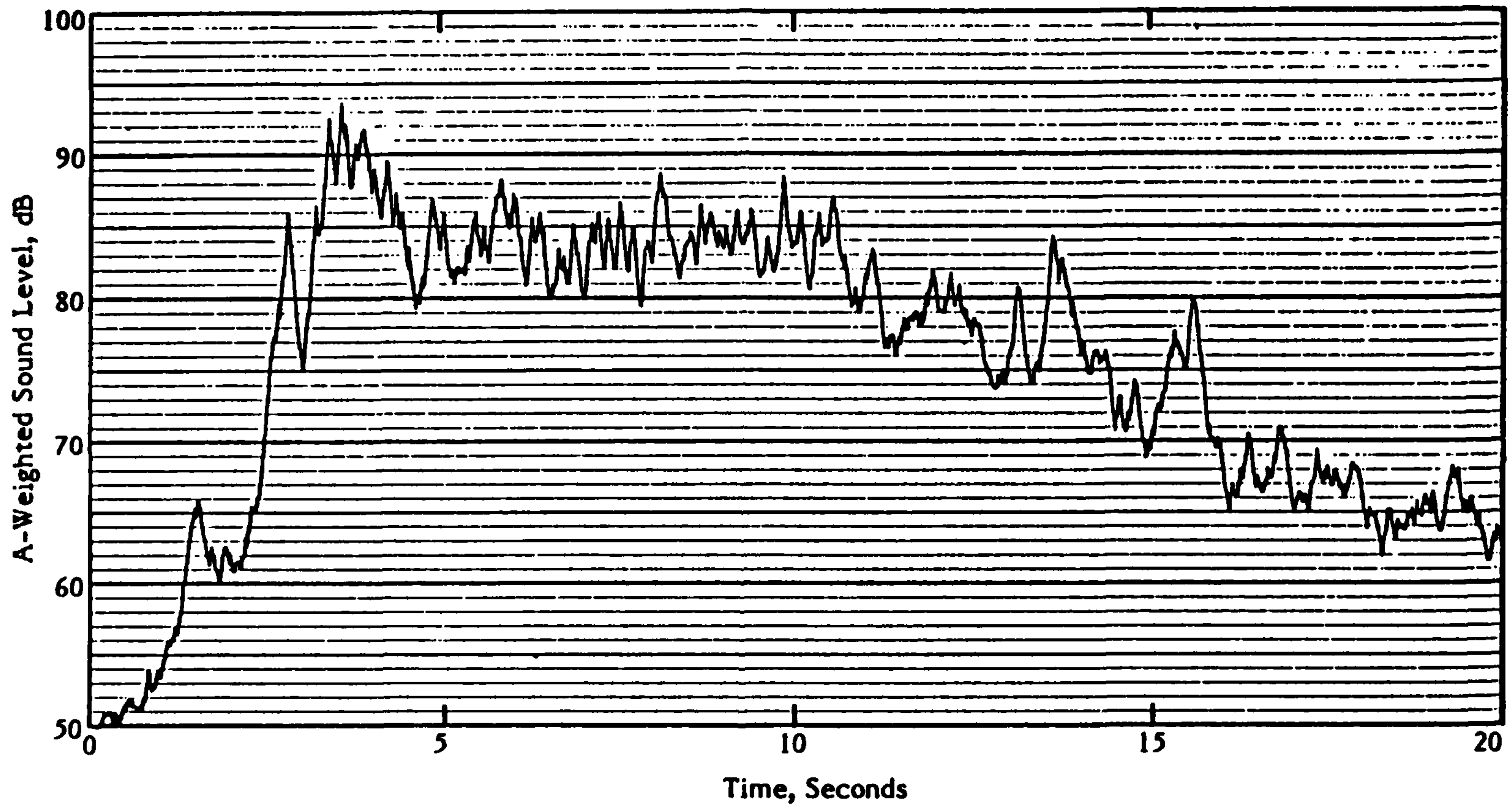

Figure 3. Time History of A-Weighted Sound Level of FB-111 at TA Altitude, One Mile Off-Track.

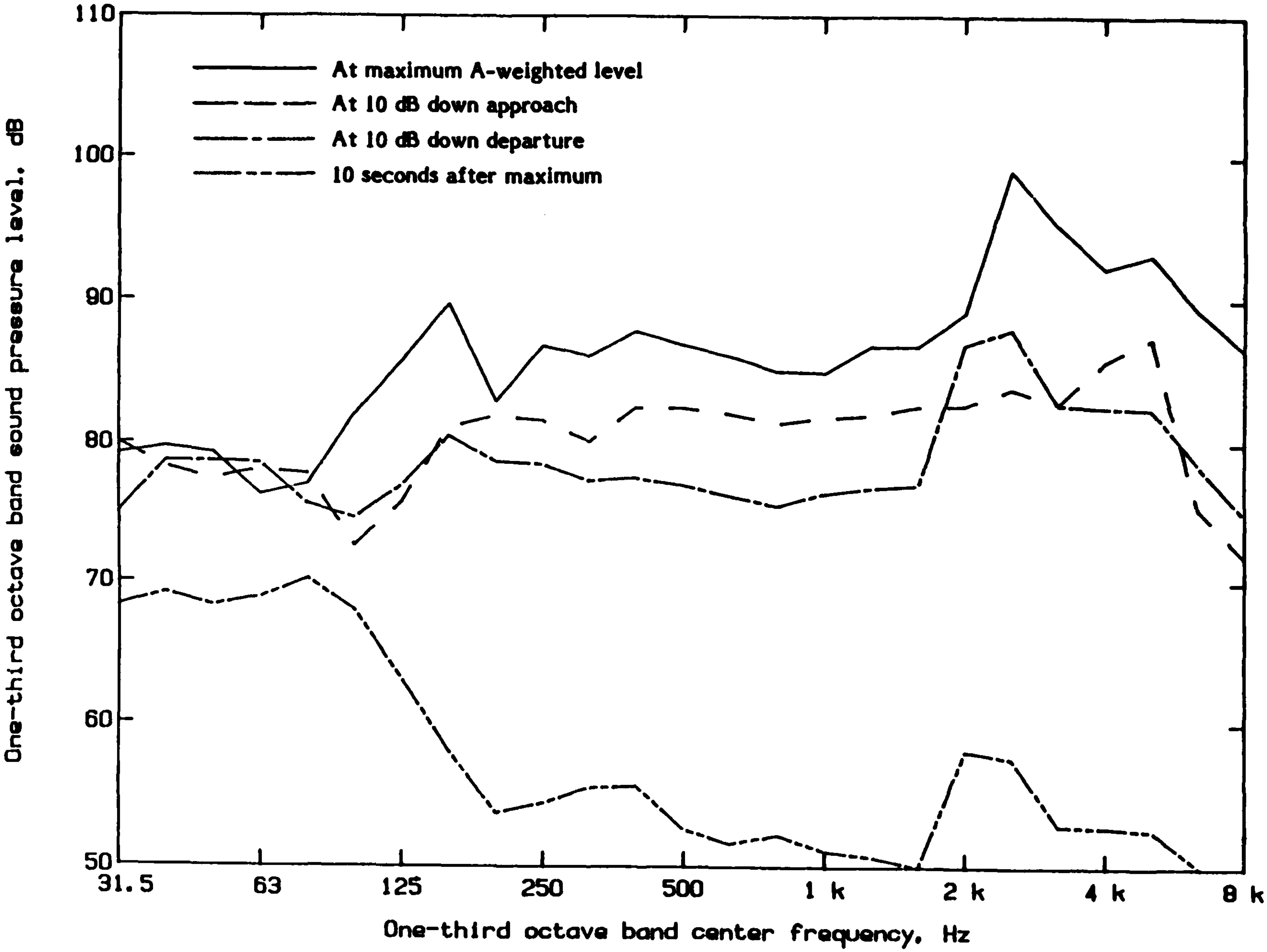

Figure 4. B-52H Spectra, TA Flight.

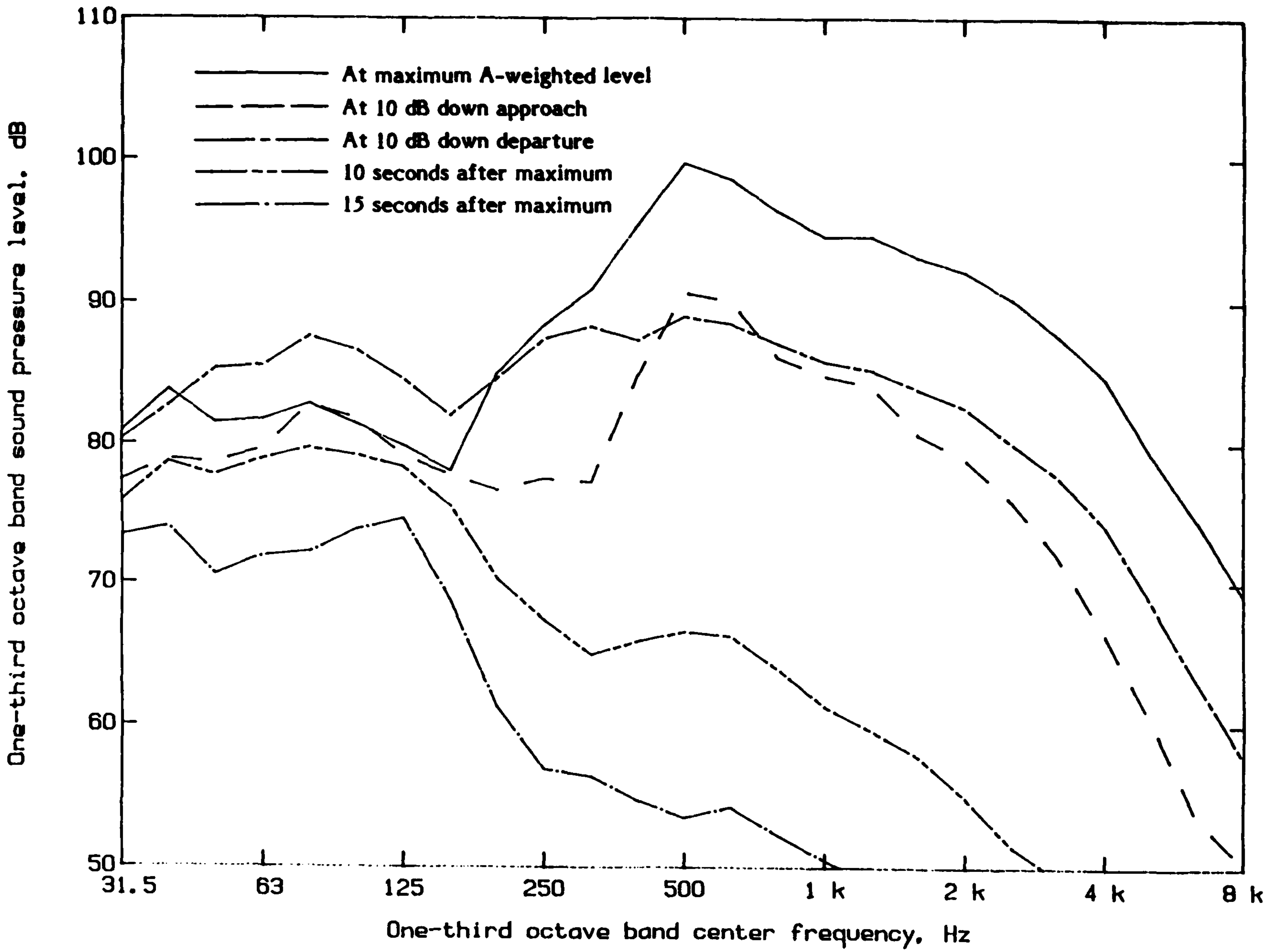

Figure 5. B-1B Spectra, TA Flight.

direct physiological effect, is not expected to occur for people exposed to noise along these routes. Noise impact, if it occurs, will consist of intrusiveness and annoyance.

Starting with L_{dn} as the prima facie metric, there are two questions which must be answered:

- o Is A-weighting appropriate? C-weighting has come into favor for assessing impulsive noises (sonic boom, artillery fire) where low-frequency content can cause structural rattling.[5-7] Those environments are dominated by low frequencies, and rattling can be a major effect. Rattling of structure or windows by MTR operations would be marginal at a time when audible noise is well into the intrusive range. One would expect, therefore, that audible intrusiveness (characterized by A-weighting) would mask any audible sounds created by rattling. However, the ear's ability to discriminate between the direct noise of the aircraft and the nominally-masked sound emitted by rattling windows, bric-a-brac, etc., cannot be discounted. Nevertheless, it is difficult at this time to conceive of a credible justification for other than A-weighting. The question of the potential need for C-weighting should be kept open as a parameter to be examined in future studies of numerous response operations at existing and lower altitudes employed on MTRs.
- o Does equal-energy adequately address the sporadic nature of MTR operations? This is a unique aspect of MTRs, and can be answered in the short term only by an examination of the range over which L_{dn} has been validated. This will be a key issue to be addressed in future psychoacoustic studies.

3.0 ORIGIN AND DOMAIN OF L_{DN}

The day-night average sound level, L_{dn}, evolved from the concept that complex noise environments could be quantified by a single number which incorporated adjustments for spectral content and temporal characteristics. At the risk of oversimplification, L_{dn} can be considered to be based on the following:

- o Spectral content of audible sound can be accounted for by the A-weighting curve. Other noise metrics (perceived noisiness, sones, speech interference level, etc.) have been shown to be more precise in particular cases; see, for example, Reference 8. In practice, the A-weighted sound level correlates well with specialized metrics with complex frequency weightings, and are considerably easier to measure.

- o Laboratory data such as those in References 9 and 10, and shown in Figure 6, indicate that trade-offs between sound level and duration can be quantified by a 3 dB level change corresponding to a doubling of duration. This applies fairly well for durations above about 3 to 4 seconds and up to about 1 minute. This relation corresponds to equal-energy and, where valid, simplifies measurement and calculation of noise exposure. The contribution of a single event is measured by the time-integrated measure, sound exposure level (SEL).

- o The equal-energy concept can be extended to the total duration of a number of separate events. This type of metric has a very simple physical interpretation and mathematically represents a number-of-event adjustment of $10 \log_{10} N$. It has been validated by laboratory and field studies, discussed later on in this report.

- o A nighttime penalty of 10 dB is based on presumed increased activity interference effects at night. As determined from social surveys, the most noise-sensitive activity during the day is speech communication, while the most noise-sensitive activity at night is sleep.

These elements define metric components which are basic to the quantification of noise intrusion. The ultimate validation of any noise metric comes from studies in real community situations. Numerous such studies have been conducted with a consensus tending to support L_{dn} for most noise intrusion situations. Figure 7 shows the range of major community noise/response studies supporting L_{dn} and equivalent metrics. Coordinates are the number of events (including the 10 dB nighttime penalty) and the average

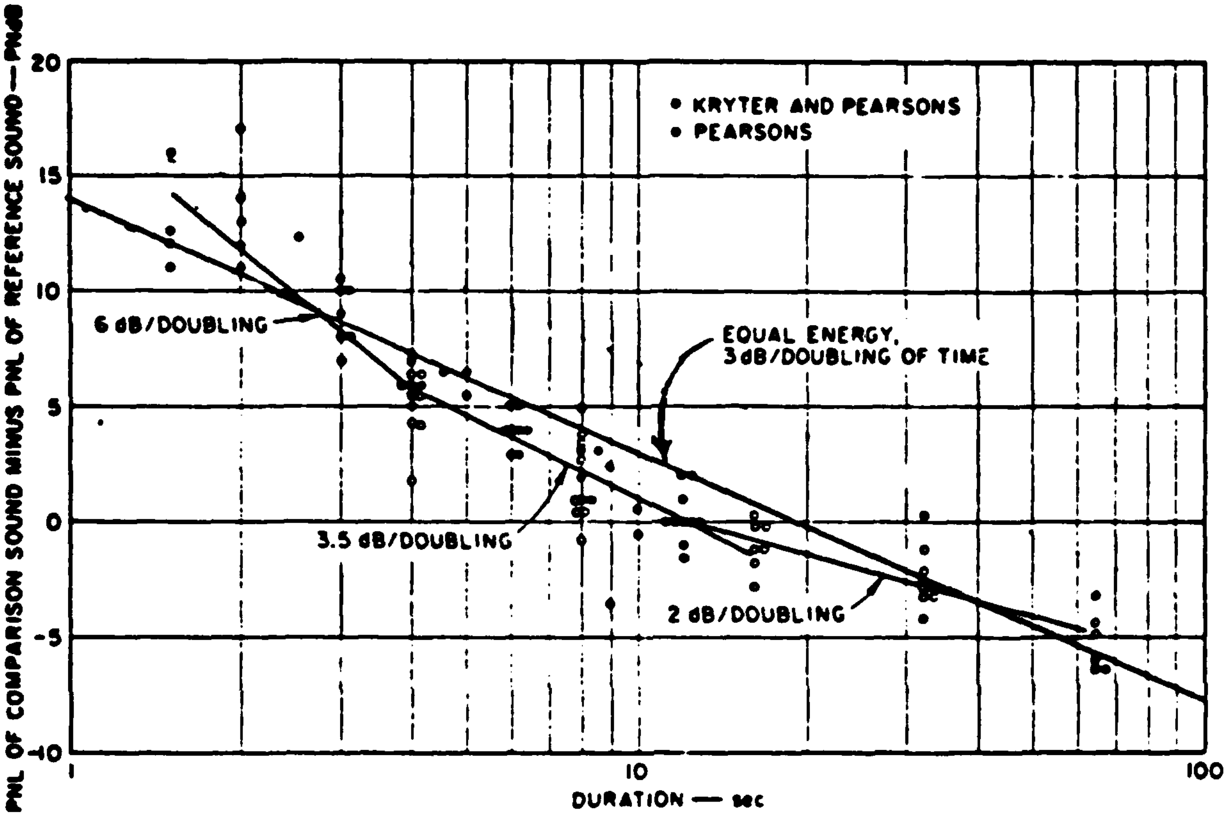

Figure 6. Summary of Equally Acceptable Noises of Various Durations (Combined Tests for Durations of 1.5–64 sec from References 9 and 10).

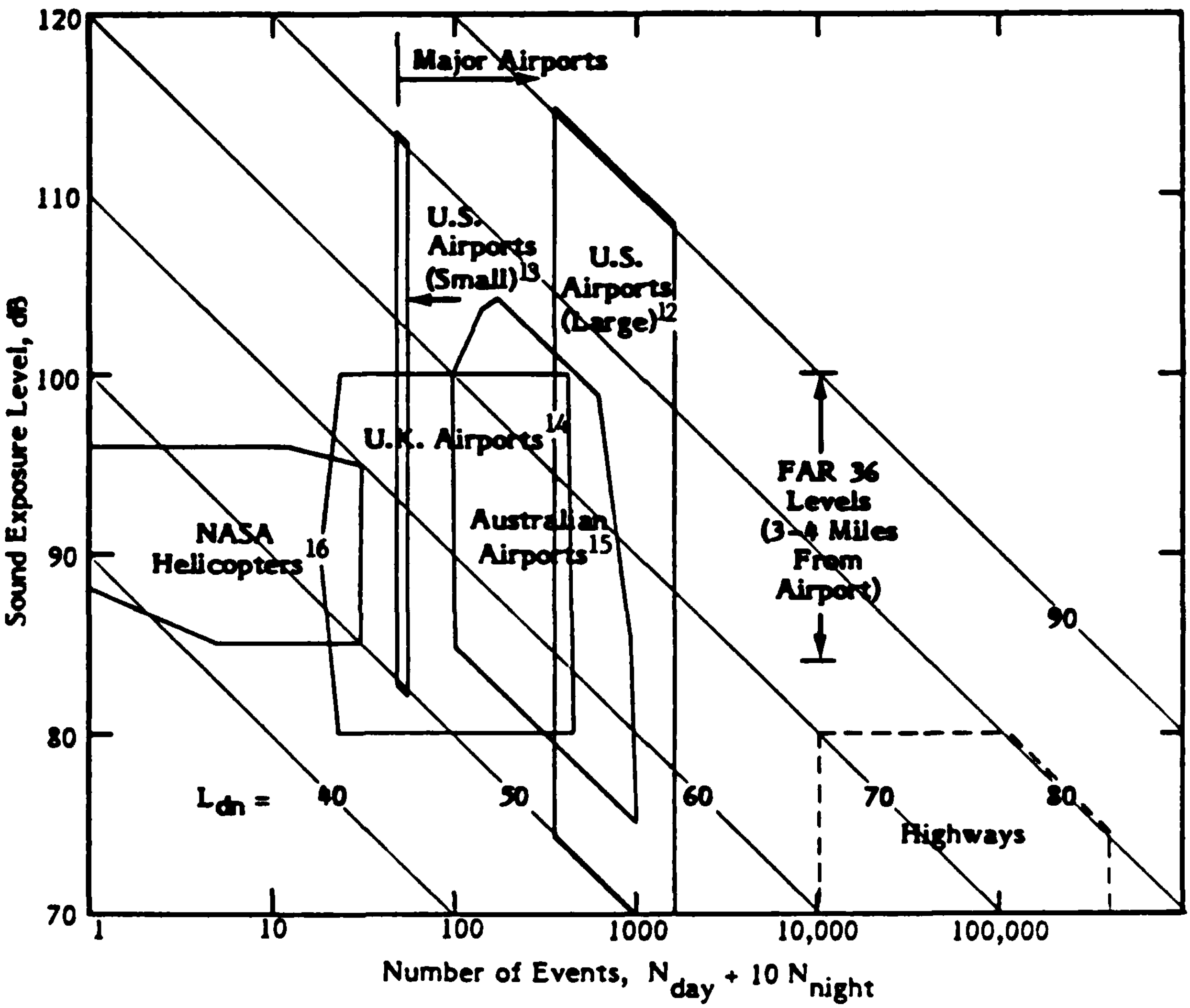

Figure 7. Sound Exposure Level and Number-of-Events Domain of Socioacoustic Studies Supporting L_{dn}

SEL per event. Diagonal lines show corresponding values of L_{dn} which can be interpreted to imply constant levels of community response (e.g., percent highly annoyed). Also indicated are typical airport noise levels (based on FAR certification levels[11]) and a lower threshold of about 50 operations per day for major airports. Five key aircraft noise studies are shown:

- FAA studies around seven large[12] and two small[13] airports in the U.S.
- A recent major study in Great Britain,[14] around Heathrow and other airports.
- A recent major study around five airports and air bases in Australia.[15]
- A recent controlled experiment, performed by NASA, in which helicopter operations down to one per day were studied.[16]

A common feature of these studies is that all were accomplished using well-designed procedures and sampling techniques, and benefited from earlier pioneering studies. A fundamental result is that all tended to support a $10 \log_{10} N$ event factor.* This was of particular significance in the British study, since it supersedes the earlier Heathrow studies[17,18] which had supported the $15 \log_{10} N$ adjustment of the Noise and Number Index (NNI).

Non-aircraft (non-impulsive) noise is also well described by L_{dn}. The general environment of highway noise, for which L_{dn} is widely accepted as a metric, is sketched in Figure 7. This region of the noise exposure map in Figure 7 is diametrically opposite the exposure for MTR operations, but shows the breadth over which L_{dn} and the $10 \log_{10} N$ rule are applicable. Other environments which fit this rule are railroads (line operations fall near the NASA Helicopter Study) and electric transmission line corona noise[19] (very sporadic, with N less than one per day in some cases, but very low sound exposure levels and hence low levels of community response).

Laboratory studies of number of events also support $10 \log_{10} N$. One such study is that by Rice,[20] where subjects were exposed to four to 64 events per hour with peak indoor levels of 45 to 85 dB(A), equivalent to outdoor SEL of about 70 to 110 dB. This experimental domain, if sketched on Figure 7, would fall in the same areas as major airports. The results showed some nonlinearity in the detailed level versus number relationship, but overall supported $10 \log_{10} N$. A caution with regard to Reference 20 (or

*The statistical findings in these studies usually showed only that any factor in the range of 8 to 12 times $\log_{10} N$ could be supported within the accuracy of the results.

any other laboratory study) is that real-world conditions could not be fully duplicated. Various levels were obtained by attenuating or amplifying the same set of flyover recordings (eliminating the real-world variability and the tendency for duration and level to be inversely related), and the subjects were not in a true home setting. Nevertheless, this type of study does document the response of people, and provides a very valuable controlled environment.

This may be quantified by prediction of the probability of high annoyance equal to the familiar "percent highly annoyed" relationship.[21]

Other factors can play a role in intrusiveness. It is feasible that a given noise would be more intrusive in a quiet environment than a noisy one. One series of laboratory experiments showed that decreasing the difference between an aircraft "signal" and the ambient background (highway) noise about 20 dB made aircraft noise about 5 dB less intrusive.[22] That study also showed that subjective response to individual events correlated well with a linear relationship for maximum level of the intruding aircraft noise event with a slope slightly greater than unity rather than 1.0 as would be required for a model based on L_{eq}. A relationship <u>other than L_{eq}</u> has not been clearly demonstrated by the results of community studies such as those summarized in Figure 7. The effect of ambient noise is real, but should be accounted for, if necessary, by adjusting criteria for acceptable levels, not by adjusting the physical measure of the noise environment.

Response of communities to aircraft noise is well-documented by studies such as those indicated in Figure 7. Universal community response curves have been synthesized from these; the one by Schultz[21] is the most widely accepted. There is some controversy over details of this type of synthesis,[23,24] and there is a question as to whether the impact of various sources (aircraft, railroads, highways) at a given level is the same.[25-28] Much of this controversy is centered around coalescing various subjective annoyance ratings and some differences may exist because of social attitudes to various sources. However, the basic quantification of the currently common types of noise exposure by the L_{dn} metric does not appear to be a major issue.

Analysis of another type of noise exposure, single impulsive sounds such as sonic boom or artillery blast, has employed L_{dn} with C-weighting instead of A-weighting.[6] While the supporting data on community response to such events are less complete than for aircraft or highway noise, a C-weighted L_{dn} appears to provide a reasonable basis for predicting response to the integrated noise exposure for such events.

MTR noise environments generally have a number of events below 10 per day. For the SAC route studied in Reference 2, maximum SEL values were in the range of 105 to 110 dB. This environment lies in the upper left corner of Figure 7, where there are no community response data. The bulk of community response data are at higher numbers of events and at lower sound levels. There are credible studies at comparable sound levels and higher numbers and at comparable numbers and lower levels. The projection of available data into the MTR domain requires extrapolation of either sound level or number of events.

As typical MTR operations are reasonably well surrounded by credible data, however, it is not unreasonable to perform this extrapolation. An extrapolation beyond the domain of both number of events and sound level would be questionable; isolated aircraft buzzing incidents cause reaction well above what L_{dn} would predict.*

It has been suggested that for MTR L_{dn} should be calculated on the basis of either a nominal 200 flying days per year (versus 365 calendar days) or on the number of actual days flown. Studies of community response to aircraft noise have generally calculated exposure on average annual operations, even though not all flight tracks are active on all days. Days with no operations provide relief from intrusiveness, and should be accounted for. However, MTR operations are not as regular as airport operations, and exhibit substantial variation throughout the year. Particular training phases or exercises can exist for periods of weeks or months, so that an annual average can underestimate impact in some cases. It is recommended, therefore, that L_{dn} be based on the (energy) average sound level for the total operation over the busiest (calendar) month within any given year. The use of a calendar month for an averaging period is employed for the sake of simplicity, in place of a more rigorous requirement to average over <u>any</u> consecutive 30 day period.

Our conclusion is that L_{dn} (based on a period of one calendar month) is an appropriate and practical baseline interim noise metric for evaluation of MTR environments. (The addition of an onset correction to this baseline metric is discussed in the next section.) The argument leading to this conclusion may be summarized as follows:

*An extreme example is the September 1984 incident at Ocean City, Maryland.[29] A public relations director for the city arranged for a C-5A to perform a goodwill flyover along the beach, but neglected to issue press releases or inform anybody. The two passes at 500 feet AGL generated numerous complaints and frightened hundreds (or thousands, depending on the news account) of people. The current project does not address this situation; it is directed at routes with sporadic, but expected, operations.

- With good justification, L_{dn} is the metric of choice for evaluation of most current types of community noise.
- There are no supporting community response data to cover MTR flight conditions. However, there are data at surrounding conditions of level or number of daily events which make extrapolation to MTR conditions a very reasonable compromise for an interim metric.
- There are no data which indicate that L_{dn} would be incorrect under MTR conditions.
- Because the evidence is circumstantial, it is essential to the Air Force's needs that psychoacoustic studies be performed to obtain supporting data under MTR noise conditions.

Cumulative Noise Descriptor

Based on the above concepts and on the additional consideration of the effect of onset rate discussed in the next section, it is recommended that the descriptor for cumulative noise from one or more MTR events over the busiest calendar month be called the onset rate adjusted monthly day-night average A-weighted sound level, abbreviated as L_{dnmr}, in decibels (unit symbol dB), which is calculated as follows:

$$L_{dnmr} = 10 \log_{10} \left[\sum_{i=1}^{N_d} 10^{L_{AEr}(i)/10} + 10 \sum_{j=1}^{N_n} 10^{L_{AEr}(j)/10} \right] - 10 \log n_m - 49.4, \text{ dB} \qquad (1)$$

where $L_{AEr}(i)$ and $L_{AEr}(j)$ are the A-weighted, onset rate adjusted, sound exposure levels (to be defined in the next section) of the ith and jth single events during daytime and nighttime periods, respectively. The summations are taken over the corresponding total number of such events, N_d and N_n, where N_d and N_n are the number of events for all days in the busiest calendar month (i.e., the month with the highest total operations $N_d + N_n$) during the daytime (0700-2200) and nighttime (2200-0700), respectively, and n_m is the number of calendar days in this busiest month. (The constant 49.4 is equal to ten times the logarithm, to the base 10, of the number (24X3600) of seconds in 24 hours.) The factor of 10 for nighttime events is consistent with the nighttime adjustment employed for day-night average A-weighted sound level.

When all single events have the same A-weighted, onset rate adjusted, sound exposure level, the value of the onset rate adjusted monthly day-night average A-weighted sound level is:

$$L_{dnmr} = L_{AEr} + 10 \log (N_d + 10 N_n) - 10 \log n_m - 49.4, \text{ dB} \qquad (2)$$

where L_{AEr} is a constant A-weighted onset-rate adjusted sound exposure level for all events.

4.0 THE EFFECT OF ONSET RATE

As discussed in Section 2.0, a unique (i.e., different from aircraft around airports) aspect of MTR noise is that the events are brief and have short onset times. It was evident in the field study[2] that surprise can be a major factor in the noise impact of these operations. Noise signatures from B-52s, as shown in Figure 1, had maximum onset rates in the range of 5 to 7 dB per second.* This diminished with increasing slant range off-track, and, while more rapid than airport noise events, did not seem remarkable. The high speed aircraft (B-1 and F/FB-111) exhibited onset rates from 15 to 25 dB per second. This was apparently related to source directivity, and did not in general diminish with increasing slant range to the side of low altitude flights. The suddenness with which these high speed aircraft became audible was striking. It appears that some metric adjustment is appropriate to account for this.

Data on the effect of rise time on perceived noisiness are scarce. Figure 8 summarizes data from four sources.[9, 30, 31, 32] Assumptions made in adapting these data are discussed below. However, it may be briefly noted at this point that there are two different trends, plus a transition region. First, as an aircraft noise exposure changes from steady to that of an approaching source, intrusiveness increases because it carries with it a sense of approach, hence increased anxiety.[30] Second, rapidly increasing noise, faster than 10 dB per second, may be classified as having an impulsive character,[31] and increases above this cause greater perceived impact. These trends are seen in Figure 8, which also includes an impulsiveness adjustment from an early version of an ISO community noise standard.[32] These trends have been plotted relative to a common steady-state reference, which results in a U-shaped transition to connect them. This transition suggests a minimum impact region for onset rates in the range of 5 to 10 dB per second, corresponding to the B-52 onset time. This is consistent with subjective observations that B-52 flyovers were less spectacular than expected,[2] although one should not draw conclusions based on limited anecdotal information. However, it is reasonable to expect such behavior, since at some rapid (but not impulsive) onset time the noise tends to be perceived as a clear, unsurprising single event, obviating the anxiety associated with slow indeterminate approach.

The data in Figure 8 are based on the following interpretation of the source material:

*Onset rate, nominally equal to the average rate of change of level during the onset of the MTR noise event, is defined more precisely at the end of this section.

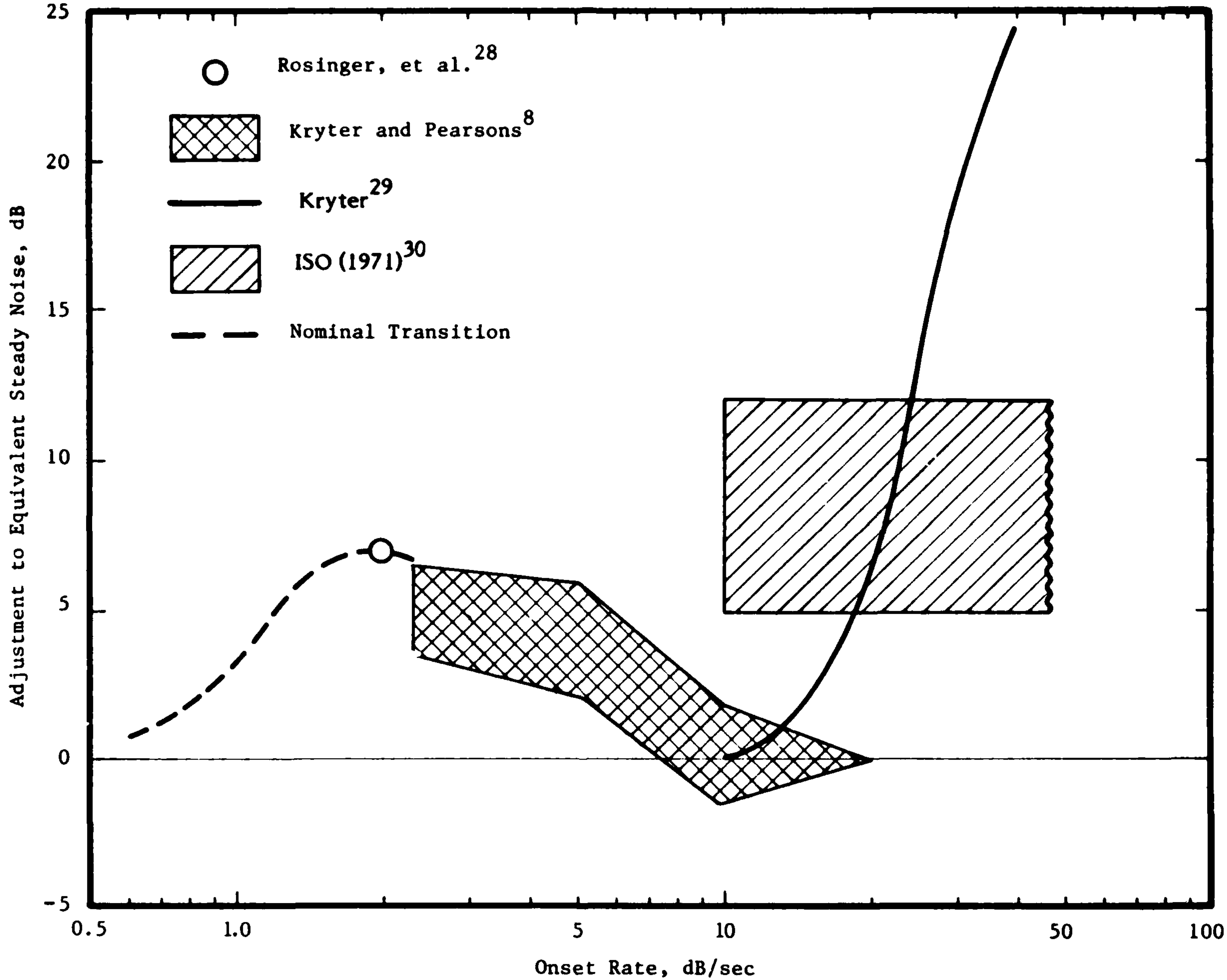

Figure 8. Data on Effect of Onset Rate on Intrusiveness or Annoyance of Transient Sounds.

- The impulsive adjustment for onset rates, above 10 dB per second, is Kryter's suggested correction for noise measured at the listener position (Figure 5.20 in Reference 31). It is based on a synthesis of several studies which included sonic booms heard indoors and outdoors,[33] artillery fire heard indoors,[34, 35] and various noise bursts and impulsive sounds.[36, 37] The curve is plotted with the same values as in Reference 31. However, in that publication, the abscissa is labeled as the ratio between impulsive and background noise, each measured as one-second energy averages, with the background measured during the second before the impulse. For present purposes, this has been interpreted as equivalent to the rise time in decibels per second, which matches for a simple ramp-shaped onset function. This may overstate the effect for the aircraft represented in Figures 2 and 3, whose onset times did not maintain their maximum rates all the way to peak levels.

- The adjustment of +7 dB, at 2 dB per second, is the nominal result for a 15 second ramp-up of 30 dB (from Reference 30 as interpreted in Reference 31).

- The data for Reference 9, which lacked an absolute reference, were plotted so that the relative adjustment factor for onset rate corresponded, approximately, to that of Reference 30.

- The region noted for ISO/R 1996-1971 represents a 5 dB penalty for impulsive sounds.[32] It has been sketched in for the region above 10 dB per second (Kryter's definition of an impulse) and over a range of the ordinate scale corresponding to, but 5 dB above, the range of the non-impulsive adjustment, i.e., the 0 to 7 dB range associated with steady-state to the Reference 30 data point.

While the data in Figure 8 are believed to represent the best information available, they are somewhat tenuous for application to the current situation. Nevertheless, they must be utilized until better data are available. The tenuous nature of this application dictates that the recommendation be conservative. We therefore conclude the following:

1) The baseline reference should be at +7 dB relative to steady-state sound. This data point falls in the range of typical airport/airbase flyovers (the application of Reference 30), and should be presumed to be the baseline situation for socio-acoustic data used in planning community response around airports.

2) The minimum adjustment at an onset rate of 5 to 10 dB per second should be ignored, even though its use might be tempting for B-52 operations. This is a conservative decision, in that we should not try to justify (from these data) higher levels than current planning procedures allow. To some degree, this compensates for the fact that a tone penalty is not used for B-52Hs, even though they have distinct tonal qualities.

3) The maximum impulse correction should be 5 dB, in accordance with ISO/R 1966-1971 (Reference 32).

4) A transition between no adjustment and the 5 dB adjustment should be based on Kryter's curve,[31] with a slight degree of conservatism because of the possibility (noted above) that the onset rate adjustment may overstate the effect for military aircraft.

5) Additional support for the maximum correction of 5 dB for onset rate is also provided by the results of Pearsons and Bennett.[38] They report the results of relative noisiness judgements made on various time varying signals with an aircraft noise spectral content. The time histories evaluated included a typical triangular rise and fall pattern with an onset and decay rate of 2 dB/second as well as an abrupt "square wave" type pattern with, ideally, an infinite onset or decay rate and a steady 10 second on-time. The data indicate that for the same sound exposure level, the "square wave" time pattern would be judged approximately 5 dB noisier when evaluated in terms of relative A-weighted sound levels.

Figure 9 shows the recommended onset rate adjustment. It is a three-part approximation of Figure 8, with the origin adjusted accordingly. The onset rate adjustment begins at 15 dB per second, and reaches a maximum of 5 dB at and above an onset rate of 30 dB/second. This results in an adjustment (to SEL) of approximately 4 dB for the worst-case B-1 overflight reported in Reference 2. Practical considerations dictate the additional constraint that no onset rate adjustment should be applied if the maximum A-weighted sound level of the overflight event, measured with a system with a time response equivalent to FAST, does not exceed the ambient sound level by at least 15 dB.

The incorporation of an adjustment factor for onset rate into the noise metric for evaluating MTR acoustic environments will require an addition to the basic noise prediction model for such operations to define the onset rates. It is anticipated that this

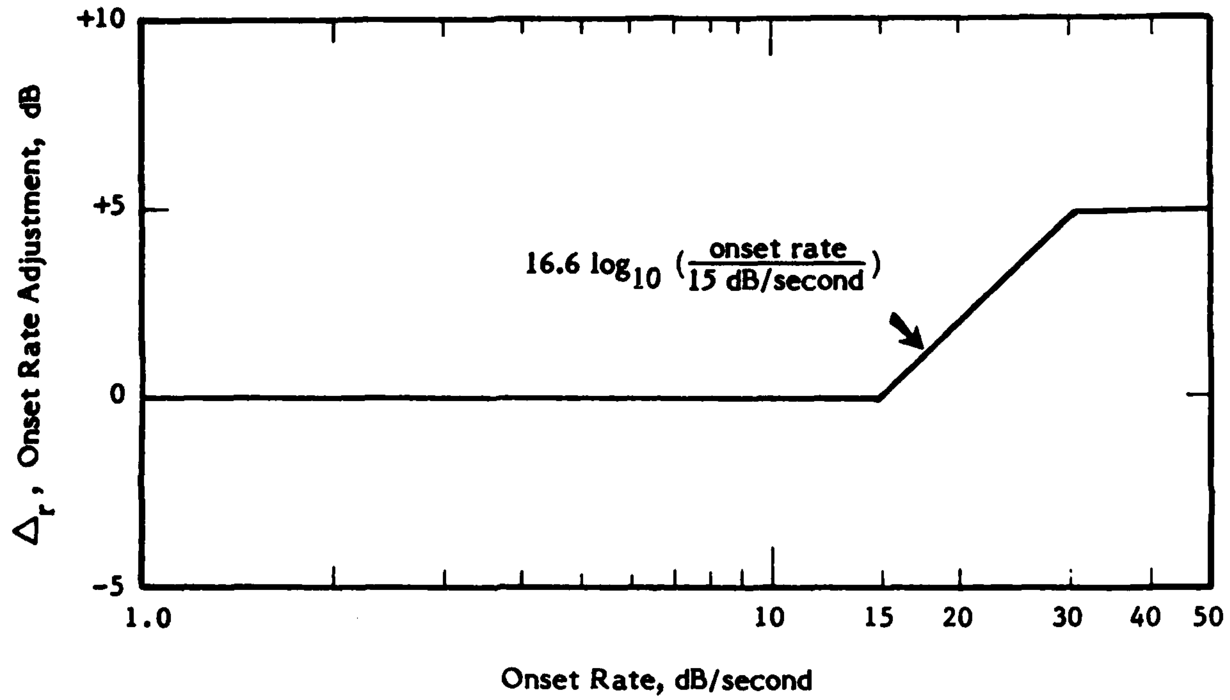

Figure 9. Recommended Adjustment to SEL for Onset Rate

addition will be based primarily on analysis of existing and planned noise signature measurement from low altitude, high speed flights supplemented by simple analytical models for the time history of such noise sources.

Single Event Noise Descriptor

Based on the above concepts, it is recommended that the noise descriptor for a single sound event with a rapid onset rate characteristic of MTR noise be called the onset-rate adjusted sound exposure level, abbreviated as L_{AEr}, in decibels (unit symbol dB) and is equal to the sum of the A-weighted sound exposure level, L_{AE}, and an onset rate adjustment, abbreviated Δ_r, in decibels:

$$L_{AEr} = L_{AE} + \Delta_r \text{ , dB} \tag{3}$$

The onset rate adjustment, Δ_r, which is applied only when the maximum A-weighted fast sound level, L_{AF}, of the event exceeds the ambient level by at least 15 dB, is equal to:

$$\Delta_r = \begin{cases} 0 & \text{, onset rate} < 15 \text{ dB/second} \\ 16.6 \log_{10}\left(\dfrac{\text{onset rate}}{15 \text{ dB/second}}\right) & \text{, } 15 \leq \text{onset rate} < 30 \text{ dB/second} \\ 5 & \text{, onset rate} > 30 \text{ dB/second} \end{cases} \tag{4}$$

The onset rate is equal to the rate of change, in decibels per second, of the A-weighted fast sound level, L_{AF}, of the overflight signal between the time the signal first exceeds the ambient level by 5 dB, and the time the signal first exceeds a level 5 dB below its maximum value. This onset rate may be measured, or predicted by a suitable model to be defined.

5.0 RECOMMENDATIONS AND SUMMARY

Operations on low level MTRs generate a unique noise environment unlike other community noise environments. A review of available information on the nature of, and potential subjective response to, this environment has been carried out. The noise exposure from MTR operations is well below threshold limits for hearing damage or other physiological effects. However, based on this review, an interim noise metric is recommended for evaluation of the potential annoyance response of communities to MTR noise environments.

This recommended interim noise metric can be defined as follows.

- o The numbers of events should be accounted for by a cumulative noise metric called the onset rate adjusted monthly day-night average, A-weighted sound level, abbreviated L_{dnmr}, based on an integration period equal to the calendar month with the highest number of operations.
- o The spectral content and effect of onset rate for a single MTR noise event will be accounted for by an onset rate adjusted, sound exposure level, abbreviated L_{AEr}, equal to the sum of the A-weighted sound exposure level L_{AE} and an onset rate adjustment Δ_r. This adjustment is applied only when the maximum A-weighted fast sound level of the event exceeds the ambient by 15 dB.
- o For MTR noise events with an onset rate equal to or less than 15 dB per second, the onset rate adjustment Δ_r will be 0. For onset rates between 15 and 30 dB per second, the onset rate adjustment, in decibels, is equal to $16.6 \log_{10} \left(\frac{\text{onset rate}}{15 \text{ dB/second}} \right)$. The onset rate adjustment is 5 dB for onset rates greater than 30 dB per second. This onset rate adjustment provides a noise penalty to account for increased intrusiveness due to the surprise factor of low level, high speed aircraft operations.
- o Impact may be assessed in terms of the probability of high annoyance, utilizing existing relations between L_{dn} and annoyance.

These recommendations are based on the best available data, very little of which is directly applicable to MTRs. Until applicable data are available, the recommendations are supported only circumstantially, or by the argument that there are no data to show that anything else is better.

To protect Air Force needs in the long run, it is essential to conduct formal psychoacoustic studies which will provide an adequate data base to support or revise, if necessary, this interim noise metric.

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